[Auction]omics

August 7, 2017

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington, D.C. 20554

Re: Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, Docket No. 12-354

Dear Ms. Dortch:

Qualifications and Subject Matter

1. My name is Paul Milgrom. I am the Shirley and Leonard Ely professor of economics at Stanford University, and professor by courtesy of the Stanford Graduate School of Business and of the Stanford School of Engineering. I have received various academic awards and honors, including membership in the US National Academy of Sciences, fellowship in the American Academy of Arts and Sciences, the BBVA Foundation Frontiers of Knowledge Award, the Nemmers Prize in Economics, a John Simon Guggenheim fellowship, an honorary doctorate from the Stockholm School of Economics, the Golden Goose award, and several others. I am the author of three books about auctions, the most recent of which, *Discovering Prices*, was published by Columbia University Press in 2017. That book includes back cover endorsements from three Nobel laureates in economics and the former chairman of the FCC Incentive Auction Task Force. According to Google Scholar, my published works have received more than 80,000 citations.
2. I have extensive practical experience designing auctions, including auctions for radio spectrum. I was the co-inventor of the *simultaneous multiple round auction*, which has been used repeatedly by the FCC for its spectrum sales. I was also co-inventor of the *combinatorial clock auction*, used for spectrum sales in Canada, Mexico, the UK, Australia and several other countries. Working through Auctionomics, I also led the consulting team for the FCC that designed the recent *incentive auction* and provided its critical computational software. Besides advising the FCC, I have advised the governments of Canada, Australia, Mexico, Germany, and the UK on spectrum auction design, and private clients on auction design or bidding for spectrum, Internet advertising, electricity, pharmaceuticals, financial securities, patent portfolios, fishery

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rights, commodities, and catalogue procurements.

3. In particular, I have extensive experience advising bidders in spectrum auctions in the US and other countries around the world. From 2008–10, I was the worldwide auction consultant for Vodafone, helping them to develop a London-based team and tools to bid in spectrum auctions around the world. From these experiences, I am sensitive to the challenges facing both individual and corporate bidders in complex auctions and aware of the tools and procedures they use for bidding.

4. I have been commissioned by WiFiForward and WISPA to prepare this letter to the Commission with my comments and recommendations about two topics related to the 3.5GHz band. The first concerns the proposed auction design for Priority access licenses (PALs) in the 3.5GHz band and the feasibility of auctioning licenses covering tens of thousands of census tracts. The second pertains to the characteristics of the proposed licenses themselves: their geographic size, the 3-year license term, and the renewal expectations.

The Feasibility of Auctioning Many Licenses

5. Setting the license areas to be census tracts will imply that there are more 74,000 areas available for licensing. Some have claimed that these sheer numbers would make it impractical to conduct an auction for these licenses. If a complex auction were required, this claim could have merit, but I conclude that for PALs for the 3.5GHz band, simple auctions for tens of thousands of licenses are feasible and reasonable.

6. There is clear real-world evidence that it is possible to conduct very many simple auctions on a single platform in a short period of time. As one example, the Internet auction site eBay currently has about one billion active listings for physical goods at any one time[1]. As a second example, nearly every visit to a commercial web page on the Internet triggers an auction for the right to show an ad. Google alone serves about 40,000 searches every second, and its ad revenue from auctions exceeded $79 billion in 2016[2]. The commercial success of these auctions establishes that there is no technical reason that an auction platform cannot simultaneously manage tens of thousands of PALs, nor any inherent reason that bidders must be overwhelmed by or unable to navigate such a system.

7. While these Internet examples establish the possibility of platforms to support many simultaneous simple auctions, they do not settle the question of whether similarly simple auctions are suitable for radio spectrum licenses. The kinds of auctions that the FCC has most often used in the past are more complex than the ones used by eBay or by Google. To evaluate the feasibility and appropriateness of an auction platform for

[1] http://files.shareholder.com/downloads/ebay/4927467010x0x900536/71613E08-2233-4D49-8205-0B22762530A5/EBAY_News_2016_7_20_Earnings.pdf, p.1

[2] https://abc.xyz/investor/pdf/20161231_alphabet_10K.pdf, pp. 24, 47

many Priority access licenses for the 3.5GHz band, one needs to examine the economic characteristics of these licenses from the perspective of potential users.

Economic Characteristics and Auction Design

8. Licenses to use the 3.5GHz spectrum hold tremendous potential for innovative new uses, including automated warehouses, the Internet of things, private venues, rural broadband, and further applications not yet foreseen. 3.5 GHz licenses appeal to a wide range of potential buyers, from traditional telecom companies to start-up pioneers. To manage many diverse uses, the FCC has adopted a new paradigm for 3.5 GHz license rights, mandating the use of a "Spectrum Access System" (SAS) to manage prioritized usage of the frequency. The SAS assigns absolute priority to the band's incumbent military users. PAL holders are granted second priority to use the frequency, but any device that satisfies the use-sharing protocols can operate on the band (when available) at nominal cost, under General Authorized Access.

9. A critical difference between the proposed 3.5GHz licensing scheme and the ones used for other frequencies is that, in the proposed scheme, even users without Priority access licenses can still make use of the spectrum through the GAA tier. This difference makes the bidder values for licenses in each census tract much less dependent on the assignment of licenses in other tracts. In economic terms, it limits the degree to which licenses may be *substitutes* or *complements*. This has very significant implications for auction design: the complex features of past spectrum auctions were most often designed and implemented to deal explicitly with the problems of bidding for licenses that might be substitutes or complements.

10. As an example of substitution, in some past FCC auctions, a bidder seeking to serve an area might bid separately for different "blocks," or specific radio frequencies. If the price for one block became too high, a bidder might prefer to switch to bid on a different block. As another example, a bidder seeking to serve the whole nation could, in some auctions, choose to buy large area licenses (for example, REAG licenses), or many licenses covering smaller areas (for example, Economic Areas (EAs) or Cellular Market Areas (CMAs)). If the price of large area licenses were found to be high, a bidder might choose to switch to bid instead on many licenses covering smaller areas. This qualitative response, in which a *higher* price for one license leads to increased demand for another license, is the economic meaning of *substitutes*.

11. Licenses in past auctions could also sometimes be complements. For example, in past auctions, a new entrant's business plan might call for serving a city and its surrounding areas. It might want to buy the license for a suburban or rural area only if the price of the license covering the city is sufficiently low. This qualitative characteristic, in which a *lower* price for one license leads to increased demand for another license, is the economic meaning of *complements*.

12. The substitutes and complements relationships among licenses in past spectrum auctions were important determinants of the auction designs that the FCC adopted. The

main advantage of the FCC's simultaneous multiple round auction over simpler designs is that it develops and displays substantial information to bidders about license prices before requiring the bidders to make their final commitments. The way this helps bidders was perhaps most clearly illustrated by bidding in the FCC's first AWS auction. In that auction, when the price of large area (REAG) licenses rose quickly in early rounds, the cable company consortium switched to bid on a larger number of smaller licenses to acquire similar coverage. Seeing the same high and rising prices of the large licenses, the satellite bidder consortium chose to exit, allowing itself to be outbid on licenses across the country. The bids for different licenses in this auction were deeply inter-related.

13. The general lesson is that past spectrum auctions in the US and around the world have been designed to accommodate the problem of bidding for licenses that may be substitutes or complements. The auction features employed – for example, multi-round auctions with bid switching or combinatorial package bidding – mitigated those problems, but at the cost of increased complexity, both of the auction system and of the participants' bidding problem. In auctions of large scale, such complexity makes it challenging for bidders to participate and bid effectively.

3.5 GHz Analysis and Default Auction Design

14. In the 3.5GHz band, the economics of the licenses are very different. Many of the proposed uses are very local ones; this was the original reason for the proposal to have small license areas. Furthermore, the substitutes and complements relationships among the licenses are much weaker, greatly reducing any need for the relatively complex auction designs that the FCC has traditionally favored.

15. ***Uses***: The uses proposed for 3.5GHz include some – like bandwidth for use in automated factories, warehouses or private venues – that involve small, local areas. Generally, the twin goals of promoting economic efficiency and increasing auction revenues both favor allowing local and wide area uses to coexist and compete for incremental spectrum access in congested areas. In particular, local users with high value uses should be able to bid to supply their own needs, without being forced to bargain with a third party that controls their access. This factor favors licenses covering census tracts for this application.

16. ***Substitutes***: Unlike some FCC licenses, the planned 3.5GHz licenses are not divided by frequencies, but simply establish priorities in the planned Spectrum Access System. The traditional distinction between licenses in different blocks in the same band is eliminated, so substitution between those blocks is also eliminated. And, since each planned license covers a single census tract, there is also no substitution between large and small area licenses. Bidders with limited budgets may still find some substitution among items, simply because they may be unable to afford to buy all they would like. That substitution can be important, but it is just the same as that in the Internet

auctions cited above. There is no need to incorporate the FCC's traditional features in the auction to allow for more extensive substitution among 3.5GHz licenses.

17. ***Complements***: Given the licensing structure of the 3.5GHz band, complementarities also play a relatively minor role. A provider that wishes to provide seamless coverage to its customers over a wide region can do so even if it fails to acquire PALs in an area, by using the GAA portion of the band in that area. There is no need to design the auction to enable bidders to express complex complementary values for 3.5GHz licenses.

18. ***License Term***. The relatively short, 3-year license terms provide additional flexibility, letting the highest value users acquire new license rights with reasonable frequency as their needs change. This, too, mitigates substitutes and complements, because it allows licensees to adjust their holdings as may be needed in a relatively short time frame.

19. In the absence of strong complements and substitutes, the rationale for the most complicated aspects of past spectrum auctions is largely eliminated. With the proposed large numbers of areas to be licensed, what remains is a strong case for a very simple auction design. For example, there could be a simultaneous ascending clock auction, like the one used for the incentive auction, but even simpler. In such an auction, each bidder would indicate the license areas it demands at the opening price, and prices would rise by one increment in each round in those areas with excess demand. In each round, for each area, a bidder can leave its demand unchanged, or can reduce it. The auction ends for each area, one-by-one, when there is no more excess demand.

20. Based on my experience, such an auction could be easy for bidders and fast to implement, making participation easier to encourage competition, and leading to more efficient outcomes and higher license prices. A simple bidder interface would sort the areas on which the bidder is still active from other areas, and would sort those two groups into ones in which the price is still increasing and ones in which the outcome is settled. The outcome of each round would be downloadable into an Excel or CSV spreadsheet to allow bidders to perform round-by-round analyses. The bid interface might include a CSV or Excel upload capability to specify bids, and might include sort capabilities to allow bidders to list the areas in their preferred order. Another tool might be a check-box to select all the areas within a larger area, such as a PEA. Similar capabilities have long been standard and are widely available in auctions around the world.

Promoting Investment and Allowing Flexible Reallocation

21. So far, I have taken as given that the 3.5GHz licenses would have terms of three years and no expectation of renewal. The three-year term is considerably shorter than the ten- to fifteen-year terms that have commonly been used – together with an expectation of renewal! – for many other kinds of licenses. The proposal for a shorter term was made in line with the growth expectations for what has been called the "innovation band." But is three years with no renewal the right license structure?

22. The problem of how best to set license terms and renewal expectations is hardly a new one, and has been faced by regulators around the world many times. The issues it raises have long been regarded as difficult ones. According to the traditional analysis, short licenses with no expectation of renewal lead to a risk that the incumbent licensee's investments may become stranded when the licensee changes, which can deter value-creating investment. There is no fixed license term that can fully remedy this problem, because for any fixed license term, there will always come a time when the period remaining is short. While that problem could be mitigated by creating strong expectations of renewal creating what are effectively perpetual licenses, that leads to another problem: it can block new uses and discourage innovators. The regulator's goal in setting the license term and the renewal expectations should therefore balance twin objectives: to encourage license turnover when valuable new uses emerge, and to protect investments by incumbent licensees.

23. Recent economic theory offers a new approach that greatly mitigates this potential trade-off. The solution, discussed for the 3.5GHz spectrum licenses application in Milgrom, Weyl and Zhang (forthcoming), involves two innovations. One is a new kind of license, which we call the "depreciating" license. The second is a linked secondary market for licenses. Interested readers are referred to my paper on this subject. The central economic idea is that a depreciating license has no fixed term. Instead, it depreciates periodically by a factor X and requires the licensee to repurchase that fraction to maintain its full license rights. I omit the details of this licensing system in this letter, focusing my discussion instead on a second idea, developed in the same paper, which approximates the depreciating license solution through a modification to the auction system.

24. My proposed "foothold" auction system offers bidding credits for incumbents, and would work as follows. Licenses with three-year terms would be made available for sale every three years, on a staggered schedule. The general format of the auction would be the same as described above, but for an incumbent licensee, payments would be determined differently. An incumbent that wins back its license in the auction would pay only a fraction X of the auction-determined license price. If the incumbent loses the auction, it would be compensated with a (preferably, transferable) bidding credit that it can apply to purchase other licenses. The value of the credit would be a fraction 1-X of the auction-determined license price. As an illustration, for triennial auctions, one might set X=0.5.

25. This proposed auction system gives the incumbent licensee an advantage in bidding for its license. For example, if X=0.5, then a winning incumbent would pay only half as much as an entrant would pay in the same auction. This enables the incumbent to bid more to retain its license rights, mitigating the problem of stranded investments. At the same time, if new, higher value uses emerge, the system provides an incumbent licensee an opportunity to "sell" its license rights by bidding low, so that license turnover is encouraged when more valuable uses arise. By design, the economic effect of this auction is to create something resembling an active secondary market for licenses, which integrates well with the proposed simple auction design.

A Simple Design is Possible and Desirable

26. Past spectrum auctions used designs that were suited to the specific features of the licenses they offered. The 3.5GHz spectrum auction should not be designed naïvely to mimic past auctions, but should instead be tuned to the use cases and values of this specific frequency.

27. Even with tens of thousands of census-tract-sized regions, licenses to use the 3.5GHz spectrum can be sold in a simple and efficient auction, without complexity for bidders or computational burden for the FCC. In the simplest design, licenses would be sold in a simultaneous, multiple round clock auction without switching. Prospective buyers would submit bids for their desired quantities of licenses in each area. Including standard tools would make such a system easy to implement and use.

28. The characteristics of the 3.5GHz spectrum and the FCC's priority licensing scheme obviate the need for the relatively complex auction designs that have been used to sell licenses for other frequencies. The strong complement and substitute relationships of those settings are much muted in the 3.5GHz band.

Conclusion

29. The 3.5GHz band offers novel, innovative possibilities to potential users, both new and established. It deserves and requires a smart license and auction design. Previous spectrum auctions, rife with concerns about complement and substitutes licenses, needed complex design features, but the proposed 3.5GHz licensing scheme eliminates most of those. By using short license terms, small (census tract) license areas, and bidding credits for incumbents in the auction, the total package can properly achieve the twin goals of protecting incumbent value-enhancing investments and providing good opportunities for innovative entrants with valuable uses.

Sincerely yours,

Paul Milgrom